Dynamic Full-body Motion Agent with Object Interaction via Blending Pre-trained Modular Controllers

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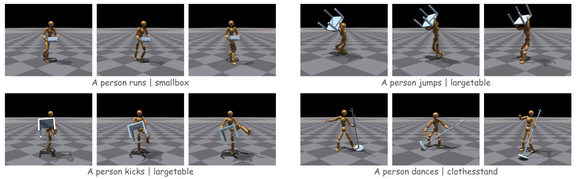
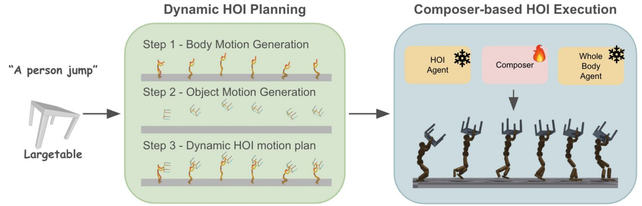
Introduction



run, jump, kick, dance while interacting with an object

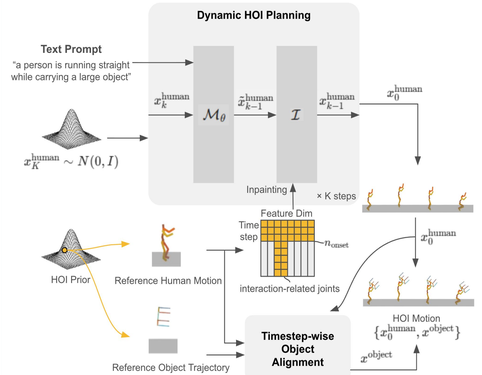
- Plan and execute physically plausible, **dynamic** and **contact-rich Human-Object Interaction (HOI)**
- Existing datasets and agents handle either HOI or dynamic motions, but **not both simultaneously**

Overview

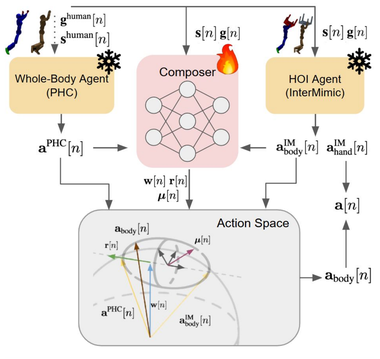


- **Dynamic HOI Planning**: Plan dynamic motions with consistent hand-object contact
- **Composer-based HOI Execution**: Efficiently learn dynamic HOI control by blending pre-trained experts

Methodology



Dynamic HOI Planning



$$\mathbf{a}_{\text{body}}[n] = \mathbf{a}^{\text{PHC}}[n] + (\mathbf{w}[n] + \mathbf{r}[n]) \odot \Delta\mathbf{a}_{\text{body}}[n] + \mathbf{U}\boldsymbol{\mu}[n]$$

$\mathbf{w}$: interpolation weights, $\mathbf{r}$: extrapolation weights, $\boldsymbol{\mu}$: exploration coeff., $\mathbf{U}$: PCA basis

Composer-based HOI Execution

Dynamic HOI Planning

- Inpaint HOI prior (FullBodyManip) into MDM during diffusion sampling
- Fix interaction-related joints after contact onset; text-aligned motion inpainting for the others
- Compute object trajectories from hand poses

Composer-based HOI Execution

- Composer predicts per-DoF inter-/extrapolation weights
- PCA-based low-dim subspaces for further exploration

Quantitative Results

Method	HOI	Physics	HOI QUALITY $C_{\%}\uparrow$	HOI QUALITY $C_{cons}\downarrow$	PHYSICAL PLAUSIBILITY $Pene_{obj}\downarrow$	PHYSICAL PLAUSIBILITY Skate ↓	PHYSICAL PLAUSIBILITY Float ↓	PHYSICAL PLAUSIBILITY $Jitter_{pos}\downarrow$	MOTION QUALITY R-Prec ↑	MOTION QUALITY Diversity ↑
MDM			–	–	–	**0.133**	29.3	9.43×10^4	**0.374**	**7.61**
HOI-Diff	✓		0.285	18.2	8.18	0.633	17.8	$\mathbf{1.56 \times 10^4}$	0.257	4.66
DAViD	✓		0.848	10.9	4.842	0.261	20.4	6.69×10^4	0.310	6.70
$Ours_P$	✓		**1.000**	**0.906**	4.196	0.217	30.1	5.93×10^4	0.332	5.56
$Ours_{P+E}$	✓	✓	0.999	2.95	**0.009**	0.786	**9.95**	4.53×10^4	0.316	3.97

Generation Quality

($Ours_P$: planning only / $Ours_{P+E}$: full planning-execution pipeline)

- $Ours_P$ achieves the **best HOI Quality** — $C_{\%}$ and C_{cons}
- $Ours_{P+E}$ achieves the **best physical plausibility** — $Pene_{obj}$ and Float, 2nd $Jitter_{pose}$

Method	$SR\uparrow$	T	$D\uparrow$	$E_{HOI}\downarrow$	$Jitter_{DoF}\downarrow$
PPO	0.227	75	0.859	59.098	0.424×10^3
PHC [26]	0.397	-	1.166	12.965	1.350×10^3
PHC_R	0.313	15	1.834	26.024	1.762×10^3
InterMimic [56]	0.376	-	2.407	21.379	0.436×10^3
$InterMimic_R$	0.310	15	2.324	34.675	$\mathbf{0.336 \times 10^3}$
$InterMimic_{FT}$	0.526	75	**7.37**	**8.635**	0.370×10^3
Ours	**0.591**	23	4.607	11.667	0.359×10^3

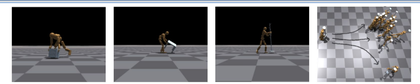
Blending	SR↑	D↑	$E_{HOI}\downarrow$
$Heuristic_{Hand}$	0.365	1.069	13.04
$Heuristic_{Arm}$	0.472	1.603	17.18
Hard MoE	0.383	2.748	20.48
Hard MoE (Joint)	0.383	2.535	26.45
$Ours_{MLP}$	0.571	3.034	18.03
$Ours_{MLP+PCA}$	**0.591**	**4.607**	**11.67**

Execution Performance

($Ours_{MLP}$: except PCA subspace exploration)

- Ours achieves the **highest success rate**
- Converges **3× faster** than fine-tuning InterMimic
- Ours blending method achieved best SR, D, and E_{HOI}

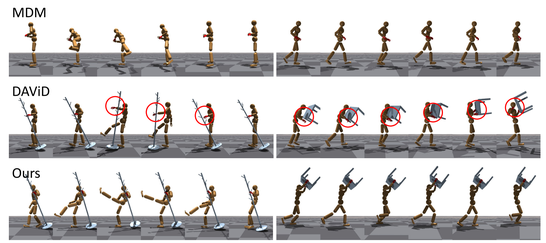
Scalability



(a) Push (b) Drag (c) Swing (d) Plan path

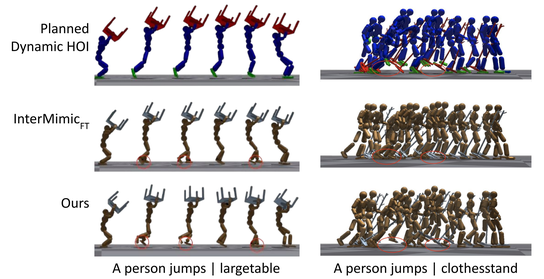
- Diverse object geometries (FullBodyManip)
- Diverse motion styles (push, drag, swing)
- Plug-and-play application — e.g., MDM → GMD enables path planning

Qualitative Results



Comparison of HOI Planning

- Ours accurately follows the text-aligned **dynamic motion** while maintaining **consistent hand-object contact**



Comparison of HOI Execution

- Ours successfully executes the planned dynamic HOI while maintaining **motion style** and **object interaction**
- $InterMimic_{FT}$ collapses to a local minimum — shuffling instead of two-foot takeoff

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